Journal of Athletic Training 1999;34(2):86–92

www.nata.org/jat

Anterior Cruciate Ligament Injury Patterns Among Collegiate Men and Women

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Objective: To determine potential patterns that cause males and females to tear the anterior cruciate ligament (ACL) while playing basketball or soccer.

Design and Setting: We reviewed data submitted to the National Collegiate Athletic Association Injury Surveillance System over the last 10 years, as well as profile data collected from collegiate certified athletic trainers.

Subjects: College athletes involved in basketball or soccer.

Measurements: Historical information was collected on those athletes involved in the National Collegiate Athletic Association Injury Surveillance System. Athletes involved in the profiling study underwent physical measurements related to flexibility, as well as a more detailed history relating to the ACL tear.

Results: College-age women involved in basketball or soccer tear their ACLs at significantly higher rates than college-age men involved in the same sports. No distinct physical or historical measurements could be attributed to this different rate of injury.

Conclusions: Although the higher rate at which women compared with men tear their ACLs has persisted over the last 10 years, this increased incidence is not clearly attributable to any physical or historical measurements that were monitored.

Key Words: epidemiology, knee, basketball, soccer

Women and girls began participating in sports in increasing levels and numbers in the 1970s. This increase paralleled the passage of Title IX, which mandated equal sports participation for girls and women in secondary- and college-level education systems. The passage of Title IX paralleled a universal women's movement, which led to increased recognition for, and acceptance of, the talents and skill levels of women both inside and outside the athletic arena.

The increase in athletic participation also increased awareness of the health and medical issues of the female athlete. It is widely accepted that musculoskeletal injuries are largely sport specific and not sex specific.[1–4] However, the differences being seen in the total number of injuries[5,6] and the incidence of serious knee injuries among men and women athletes who participate in jumping and pivoting sports have come under recent review.[7,8] In particular, the differences in anterior cruciate ligament (ACL) injury rates among men and women have come under special scrutiny.[9–13]

There are 2 primary limitations to current sports injury epidemiology data. The first is that there is no common definition of injury, measure of severity, or evaluation of exposure in athletic injury literature. This makes it difficult to compare studies and pool data. The second limitation is the evaluation of exposure. An athlete exposure is the unit of risk when an athlete is exposed to the possibility of an athletic injury. The most rigid definition of injury exposure would define exposure by the amount of time played. To conform to this most rigid definition of exposure in a team sport such as basketball, one would need to keep track of the number of minutes played by each person on the team. A less rigorous criterion would define exposure as the participation of one athlete in one practice or game where he or she is exposed to the possibility of an athletic injury. This more practical way of measuring exposure still allows for consistency across schools and across time.

Authors EAA and RD previously undertook a study[13] of available collegiate data to evaluate the incidence of ACL injuries in matched men's and women's sports across a broad sample and across multiple years. This paper will include a review of this previous study, as well as presentation of new data.

To test the hypothesis that female athletes were more susceptible to ACL injuries, authors EAA and RD originally looked at the National Collegiate Athletic Association (NCAA) database, which has a long history of experience in collecting injury patterns in a consistent method over time. The sports of basketball and soccer were chosen to study since they are sports that are both followed and reported in the NCAA Injury Surveillance System (ISS) and are played using the same rules. Injury data for the sports of men's and women's gymnastics are also tracked by the NCAA ISS. However, men and women in this sport share only the floor routine and the vault. Men's lacrosse and women's lacrosse are contact and noncontact sports, respectively. At this time, women's volleyball, and not men's volleyball, is followed by the NCAA ISS system.

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Table 1. Knee Structures Injured in Soccer (1989 to 1993)

	Men's Soccer		Women's Soccer		
Injured Structure	Number	Rate*	Number	Rate*	P†
Collateral ligament	316	0.51	192	0.62	.02
Cartilage (meniscus)	119	0.19	105	0.34	.00
Patella or patellar tendon	130	0.21	92	0.30	.01
ACL	81	0.13	97	0.31	.00
Posterior cruciate ligament	22	0.04	12	0.04	

* Rate based on injuries per 1000 athlete exposures. Athlete exposures: men's, 626223; women's, 308748.
† Probability based on χ^2 tables.
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METHODS

Data were collected using the NCAA ISS. The ISS was developed in 1982 to provide current and reliable data on injury trends in intercollegiate athletics. Injury data is collected yearly from a representative sample of NCAA member institutions.

To gain more insight into knee injuries, a new question was added to the ISS in 1989. Specific knee injuries were itemized to include injuries to the collateral, anterior cruciate, and posterior cruciate ligaments; cartilage (including the meniscus); and the patella or patellar tendon. Any or all of these structures could be included in a particular injury report. Specifically, since 1989, the enhanced NCAA ISS data on knee injuries have allowed the identification of ACL injury.

Sampling

Participation in the NCAA ISS system is voluntary and limited to the 931 member institutions (as of July 1998). ISS participants are selected from the population of institutions sponsoring a given sport. Selections are random within the constraints of having a minimum of 10% representation by each NCAA division (I, II, and III) and region (East, South, Midwest, and West). It is important to emphasize that this system does not identify every injury that occurs in each NCAA institution in a particular sport. Rather, it collects a sampling that is representative of a national cross-section of NCAA institutions.

Injuries

A reportable injury in the ISS is defined as one that "occurs as a result of participation in an organized intercollegiate practice or game, requires medical attention by a team athletic trainer or physician, and results in restriction of the student's athletic participation for one or more days beyond the day of the injury." Each reportable injury was detailed in a variety of subcategories by a single response that best described the injuries. These categories include injury mechanism (no apparent contact, contact with another player, contact with the floor) and an injury time (practice or game).

Exposures

An athlete exposure, the unit of risk in the ISS system, is defined as the participation of one athlete in one practice or game where he or she is exposed to the possibility of athletic injury.

Injury Rate

Injury rate is determined by comparing the number of injuries in a specific category with the number of athletes at risk in that category. The resulting value is expressed as injuries per 1000 athlete exposures.

RESULTS

First 5 Years, 1989 to 1993

Our initial study evaluated sex-specific knee injuries during a 5-year period from 1989 to 1993 in the sports of soccer and basketball.[13]

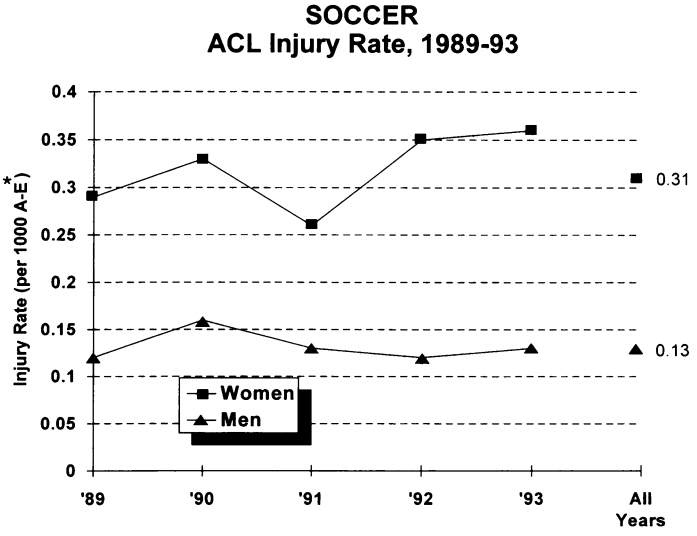

Figure 1. NCAA ACL injury rate in soccer players, 1989–1993. *A–E = athlete exposures. Reprinted with the permission of the *American Journal of Sports Medicine*.[13]

Table 2. Knee Structures Injured in Basketball (1989 to 1993)

	Men's Basketball		Women's Basketball		
Injured Structure	Number	Rate*	Number	Rate*	P†
Collateral ligament	158	0.21	181	0.28	.01
Cartilage (meniscus)	100	0.13	189	0.29	0
Patella or patellar tendon	196	0.26	158	0.24	
ACL	49	0.07	189	0.29	0
Posterior cruciate ligament	5	0.01	9	0.01	

* Rate based on injuries per 1000 athlete exposures. Athlete exposures: men's, 736026; women's, 639898.
† Probability based on χ^2 tables.
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Soccer. Data were collected in the sport of soccer in 461 men's teams (average, 92 per year) and 278 women's teams (average, 56 per year) during this 5-year period. Participation reflected 15% of the NCAA institutions sponsoring that particular sport. The higher number of men's teams reflected the greater absolute number of NCAA schools sponsoring the sport of soccer during those years and resulted in a higher number of athlete exposures. The male athlete's exposure was approximately twice that of the female athlete's exposure. Therefore, we cannot compare the absolute number of ACL injuries but must compare them over the denominator of athletic exposure, computing a rate.

Knee structures injured are shown in Table 1. The ACL injury rate in women's soccer (0.31) was more than double that of the men's rate (0.13). The difference in the ACL injury rate between the sexes was consistent in both practices and games. The mechanism of ACL injury between the sport of soccer was different in the men's and women's games. In the women's games, no apparent contact was the primary mechanism of injury (63%), followed by player contact (37%). Player contact (52%), followed by no apparent contact (48%), was the primary injury mechanism in the men's games. Women soccer players were 2 times more likely than their male counterparts to have an ACL injury as the result of player contact and 3 times more likely to obtain such an injury through noncontact mechanisms. For soccer, the ACL injury rate differences between men and women during the initial 5-year sample period are shown in Figure 1. The difference in injury rate between men and women was present in each of the years sampled and stayed consistent over the initial 5-year samples.

Basketball. Data were collected for 531 men's teams (average, 107 per year) and 576 women's teams (average, 115 per year) from 1989 to 1993. Participation values reflect 16% of the NCAA institutions that sponsored men's basketball and 17% of the institutions that sponsored women's basketball. This relatively equivalent number of teams participating in each sport reflects similar sponsorship in both sports and similar numbers of athlete exposures between men and women.

Knee structures injured in the sport of basketball are shown in Table 2. The ACL injury rate in women's basketball (0.29) was more than 4 times that of the men's (0.07). The difference in the ACL injury rate between the men and women remained consistent in both practices and games. In the women's basketball data, no apparent contact (80%) was a primary injury mechanism, followed by player contact (20%). The same pattern was evident in the men's data. For basketball, the ACL injury rate between men and women during the initial 5-year sample is shown in Figure 2. The difference in this variable was present across each of the years sampled.

Second 5 Years, 1994 to 1998

One theory concerning the disparity in injury rates suggests that a difference in the skill levels of male and female athletes when they enter college sports is responsible for the higher injury rate in women. Presumably, women come into the sports of soccer and basketball with a reduced skill level compared with men and perhaps with fewer years of training. It was felt that, as the years progressed from the early 1990s to the late 1990s, this lack of skill would be less apparent, since more women were entering their sports at earlier ages. Certainly this is reflected in the current data of the number of women playing high school basketball and soccer, as well as the general increase in participation in these sports nationally, both in community and secondary education systems.

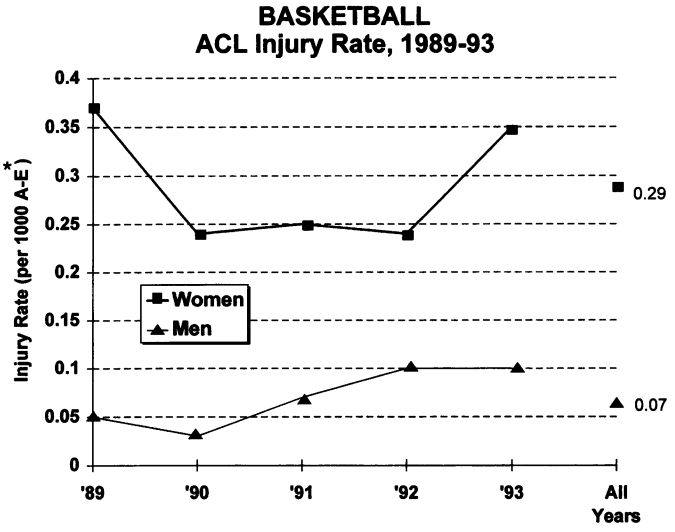

Figure 2. NCAA ACL injury rate in basketball players, 1989–1993. *A–E = athlete exposures. Reprinted with the permission of the *American Journal of Sports Medicine*.[13]

With this in mind, we recently revisited more modern data for the sports of men's and women's soccer and basketball. We again used the NCAA ISS data.

Soccer. Reviewing the data from the 5-year period of 1994 to 1998, we noted that, in comparison with men, women continued to have a higher incidence of ACL injury in soccer. This holds true for both practice time and game time (Table 3). The athletic exposures for women are approaching those for men, reflecting increasing participation of women in the sport of soccer within NCAA institutions. The ACL injury rates for men and women during the second 5-year sample are shown in Figure 3. The difference in this variable was present across each of the years sampled.

Basketball. In basketball during the 5-year period of 1994 through 1998, we again saw a consistently high pattern of injury rate in women as compared with men (Table 4). The injury rate for the ACL in women's basketball was nearly triple that of men in both practices and games. The athletic exposure for women was comparable with men, reflecting comparable participation for men and women in the sport of basketball within NCAA institutions. The ACL injury rate between men and women during the second 5-year sample is shown in Figure 4. The difference in the variable was present across each of the years sampled. Although the overall exposure in game time was significantly less than practice time for men and women, the injury rate in games was greater than the injury rate in practice among both men and women in both basketball and soccer.

Women's volleyball. We were also interested in looking at women's injury rates in volleyball, giving us another women's sport that might have similar mechanisms of injury, ie, jumping, planting, and pivoting with sudden position changes. Looking at women's volleyball in the years 1997 and 1998, we noted that women have both game and practice ACL injury rates that are substantially less than the injury rates in women's soccer and basketball (Table 5). Reflecting on these 3 sports, we found it curious that basketball and soccer share a high ACL injury rate for women when they are played very differently, one being a sport that involves a cleated shoe on grass with significant planting and pivoting, the other involving a court shoe on a wood surface that requires planting, pivoting, and jumping. Comparing basketball with volleyball, both are played on a wooden court with a shoe and involve jumping, with perhaps less sudden changes in planting and pivoting. However, women's volleyball has a significantly lower ACL injury rate than women's basketball.

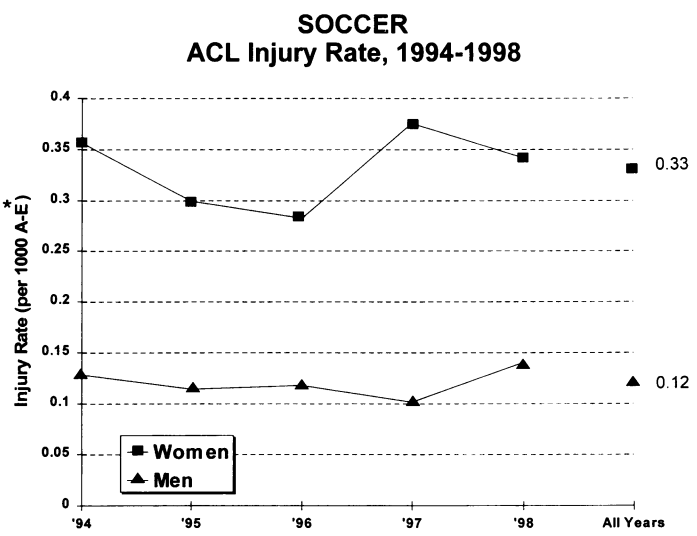

Figure 3. NCAA ACL injury rate in soccer players, 1994–1998. *A–E = athlete exposures.

DISCUSSION

Trying to further analyze the causative factors with regard to noncontact ACL (NCACL) injuries has been a difficult task. Athletic injuries result from a complex interaction of risk factors. Risk factors can be classified into 2 categories. The first category, extrinsic factors, comprises those factors related to the type of sports activity, the manner in which the sport is practiced, environmental conditions, and the equipment used to play a sport. The second category, intrinsic factors, comprises those factors that are individual, physical, and psychosocial.[14] Using this scheme, positive causation factors for an increase in ACL injuries among women are frequently divided into extrinsic factors (body movement, muscular strength, shoe-surface interface, and skill level) and intrinsic factors (joint laxity, limb alignment, intercondylar notch dimensions, ligament size, and hormonal influences). The current thought is that the increased risk of ACL injuries among women is likely multifactorial, with no single structural, anatomical, or biomechanical feature solely responsible for this increased rate.

Table 3. Total ACL Injuries for Women's and Men's Soccer (1994 to 1998)

	Women's Soccer			Men's Soccer		
Year	Total injuries	Total exposure	Rate	Total injuries	Total exposure	Rate
1998	38	111336	0.341	22	157577	0.140
1997	42	111887	0.375	14	138769	0.101
1996	29	102836	0.282	13	111448	0.117
1995	27	90377	0.299	15	131045	0.114
1994	22	61840	0.356	13	101860	0.128
Total	**158**	**478276**	**0.330**	**77**	**640699**	**0.120**

Table 4. Total ACL Injuries for Women's and Men's Basketball (1994 to 1998)

	Women's Basketball			Men's Basketball		
Year	Total injuries	Total exposure	Rate	Total injuries	Total exposure	Rate
1998	33	133773	0.247	10	145733	0.069
1997	37	156252	0.237	18	179483	0.100
1996	39	129395	0.301	16	135237	0.118
1995	47	142843	0.329	19	158333	0.120
1994	38	109125	0.348	12	127381	0.094
Total	**194**	**671388**	**0.289**	**75**	**746167**	**0.101**

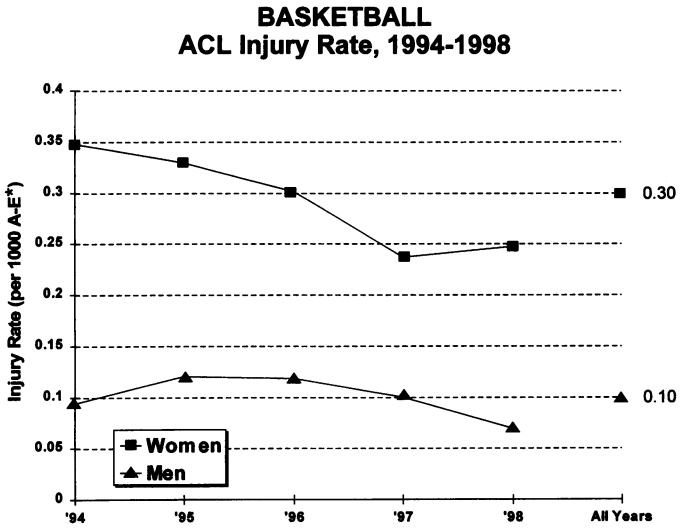

Figure 4. NCAA ACL injury rate in basketball players, 1994–1998. *A–E = athlete exposures.

The etiology of the increased risk of ACL injuries in women, particularly women who play jumping and pivoting sports, remains speculative. However, skill level continues to be implicated, especially in the early years after the enactment of Title IX. Although years of participation and experience do not equate with skill level, typically there is a positive relationship between the number of years playing a sport and one's skill level. With this in mind, we hoped that, as the years progressed into the mid 1990s, we might see a drop in the ACL injury rate in the collegiate athlete. This does not appear to be the case based on data collected by a similar method (NCAA ISS) and compared over 2 separate 5-year periods (1989 to 1993 and 1994 to 1998). This finding suggests that neither lack of skill nor lack of years of experience playing a sport is the primary causative factor for injury or that skill level has to be measured in a more rigorous method than by years exposed to an organized athletic experience.

PROFILE OF THE ACL-INJURED ATHLETE: A PILOT STUDY

In an effort to further unravel the ACL problem, the NCAA, along with a group of interested physicians and college certified athletic trainers, launched a pilot study. The goal of this pilot project was to develop a profile of variables that would be consistently present in the injured athlete. The communication network that was used was the same network of communication used in the NCAA ISS system. The variables looked at were those physical examination features, or historical features, of the athlete that could be examined or gathered by a history and physical examination. The variables were based on popular theories as to the causative factors of ACL injuries. They included physical examination features of hip range of motion, especially internal rotation, suggesting an anteverted stance; large Q-angle; hyperextension at the knee; and generalized tissue hyperlaxity. Historical features that could be elicited in this form of survey study included timing of the injury in relation to one's menstrual cycle (for women only) and the number of years played in one's sport. Certainly a description of the mechanism of injury and features such as shoe and floor or playing surface could also be included. The number of variables that needed to be collected was sizable. In order to reach statistical significance with this large number of variables, hundreds of ACL injuries would need to be recorded to produce statistical significance. Therefore, the project earmarked the ACL-injured athlete to record features that could be

Table 5. Injury Rate Comparison for Women (1998 and 1997)

		Practice			Game		
Sport	Year	Injury	Exposure	Rate	Injury	Exposure	Rate
Volleyball	1998	4	60179	0.066	3	24904	0.12
	1997	8	93778	0.085	9	38034	0.237
Basketball	1998	13	104492	0.124	20	29281	0.683
	1997	16	122537	0.131	21	33715	0.623
Soccer	1998	9	86769	0.104	29	24567	1.18
	1997	11	86511	0.127	31	25376	1.22

reviewed after the athlete was injured. The goal was to see whether there was any commonality among the injured athletes. This would produce a profile, or snapshot, of the injured athlete that could lay the foundation for which factors would be most important to study in a more rigorously controlled fashion.

Data Collection

Data were gathered from the 1996 to 1998 academic years. Two forms were used for this project. The first involved an interview-type questionnaire that reviewed medical and sports participation history; a second form included physical examination features based on the contralateral limb. All reporting from the colleges and universities was voluntary.

The data were collected by certified athletic trainers. Pictures accompanied the data collection forms to ensure that the data were collected in a consistent manner. At the beginning of the pilot project, we conducted a telephone conference call that included one certified athletic trainer from each participating athletic conference.

Population

There were 104 NCACL injuries reported (43 male, 61 females). Ninety-seven of these athletes were felt to be eligible for further analysis. The diagnosis of an NCACL was confirmed by arthroscopy in 19 cases and by MRI in an additional 48. Of the remaining 30 NCACL tears, 26 were confirmed by an orthopaedic surgeon's manual examination. Forty-nine (50%) of the athletes in this study sustained their injuries in the sports of basketball and soccer.

Mechanism of Injury

The most common reported mechanism of injury, according to the athlete, was planting and pivoting (n = 28) (Table 6). Twenty-one of the NCACL tears occurred in practice and 26 occurred in a game. Two did not report whether their injury occurred in a practice or in a game. Twelve were listed as preseason events, 29 as in-season, and 1 as postseason. Seven did not report the sport season in which their injury occurred.

Table 6. Common Mechanisms of Injury

Mechanism	Frequency	Percentage	Cumulative Percentage
Landing from a jump	6	12.2	12.2
Planting/pivoting	28	57.1	69.4
Deceleration	6	12.2	81.6
Going up for a jump	2	4.1	85.7
Hyperextension	6	12.2	98.0
Unsure	1	2.0	100.0
Total	**49**	**100.0**	

Health

Thirty-eight of these athletes (77%) reported playing 100% at the time of their injuries with no limiting physical illness, injury, or mental stress. This information was self-reported. There was no sex difference in this variable.

Menses

Menstrual data were self-reported. The date of the beginning of the last menstrual cycle before the NCACL injury was recorded. The 3 phases of the menstrual cycle were reported as follows: follicular (days 1 through 9), ovulatory (days 10 through 14), and luteal (days 15 through the end of the cycle).[15,16] Of the 38 female athletes, the mean age for onset of menses was 13.2 years. Seven (4%) of the female athletes reported being currently on birth control pills. Four of these athletes sustained their injury during the follicular phase, 1 during the ovulatory phase, and 2 during the luteal phase. Twenty-one of the females not on the pill reported the last day of their menses; 11 sustained their injury in the follicular phase, 1 in the ovulatory phase, and 9 in the luteal phase.

Sports Participation History

The mean years of participation in high school for the sport in which the athletes sustained their NCACL injury was 3.87 (males = 3.73 ± 0.65, females = 4.0 ± 0.51). Thus, most of these athletes played their particular sport in high school through all 4 years. Only 3 (11%) of the athletes reported not playing their college sport during high school. There was no significant difference between the sexes. The mean age at which the athletes first began playing their sport was 8.7 years, with no difference between the sexes (males = 8.73 ± 3.26, females = 8.58 ± 3.48).

Physical Examination Results

Thirty-six of the injured athletes submitted physical examination data. These athletes had no evidence of a hyperlaxity syndrome. Their hip flexors had normal range of motion. Twelve (33%) of the athletes had hamstring muscle tightness. Q-angles were not excessive, with males averaging 7° and females averaging 12°. Foot-thigh progression angles were also not excessive, with 92% recording a foot-thigh progression angle of less than 20°. Most athletes (90%) had measured heel height to table that was greater than 15 mm, reflecting some degree of knee hyperextension.

CONCLUSIONS

In the profile of the injured soccer and basketball athlete, the mechanism of NCACL injury was pivoting or landing from a jump. There was no evidence of comorbidity in injury or illness. These athletes were experienced, with several years of sports participation before and during high school. There was

no consistent abnormal physical examination feature, except for knee hyperextension. Females were more likely to be injured just before or just after their menses and not midcycle.

We hope that this report stimulates research to examine the multiple variables that may contribute to this difference in rate of injury. Results of such research can contribute to a safer athletic experience for all participants. We feel that this profile of the injured athlete helps us to further refine the variables upon which future studies should be performed.

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